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FILE: EB-139 D BALLOON, PORTABLE HYDROGEN GENERATOR.

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SUMMARY LETTER REPORT #1

on

WORK ORDER NO. 10
TASK ORDER NO. 30

June 20, 1964

[redacted] 50X1

March 10, 1965

Dear Sir:

This letter represents the summary letter report on Work Order No. 10, Task Order No. 30. The effort conducted under this program during the period April 20 through June 20, 1964, is described in the "Summary Letter Report on Work Order No. 1, Task Order No. 39", dated November 15, 1964.

On April 20, 1964, Work Order No. 10, Task Order No. 30, was undertaken to perform a cursory investigation of the possibility of generating 300 cubic feet of hydrogen gas using Hydripills and water with a one-package addition, and under other specialized conditions. The results of this limited effort indicated that, as anticipated, the foaming experienced under the specialized generating conditions was sufficient to necessitate further experimental work to develop a suitable generation system. Effective July 15, 1964, Work Order No. 1, Task Order No. 39, was set up to provide for a more extensive effort on the development of a satisfactory generation system. To make the discussion of the results of the two programs more meaningful, the results were integrated and described together in the "Summary Letter Report on Work Order No. 1, Task Order No. 39", dated November 15, 1964, in accord with the Sponsor's recommendation.

Sincerely,

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ABW:mg

In Triplicate

[redacted]

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CONFIDENTIAL

SUMMARY LETTER REPORT

on

WORK ORDER NO. 1
TASK ORDER NO. 39

November 15, 1964

CONFIDENTIAL

50X1

March 10, 1965

Dear Sir:

This letter report summarizes the research conducted under Work Order No. 1, Task Order No. 39, from July 15 through November 15, 1964; and also, as a matter of coherence, the results of the effort performed under Work Order No. 10, Task Order No. 30, from April 20 through June 20, 1964.

INTRODUCTION AND OBJECTIVES

During the past few years, several research efforts have been conducted on the investigation and design of experimental hydrogen generators to produce hydrogen gas on the basis of water and commercially available Hydripills® (consisting of sodium borohydride and cobalt chloride). The success of these efforts has led the Sponsor to consider a project directed toward the development of a hydrogen-generating device with the following characteristics:

(1)	Generating capacity:	300 cubic feet of hydrogen using Hydripills® and fresh water at a temperature of 55 to 75 F
(2)	Generating time:	15 minutes nominal, 25 minutes maximum
(3)	Generator:	Compact and lightweight, with minimum volume in the folded condition

(4)	Auxiliary Equipment:	2-foot-long gas exhaust hose and, if practical, a hand pump to facilitate filling the unit
(5)	Operation:	Simple and straightforward, with a one-package chemical addition.

Based on these requirements and on past experimental work with various types of hydrogen generators, it appeared that a satisfactory device might be about 3 feet in diameter by 2 feet high, with a 6-inch-diameter sealable opening for chemical and water addition and a 1-1/2 to 2-inch-diameter opening for a gas outlet. It could probably be fabricated from neoprene-impregnated nylon and use stays to rigidize the structure. The generation would require about 9 pounds of chemical in about 45 gallons of water. By the addition of all of the chemical to the water at one time in a fairly exposed state, it was expected that the generation time would be less than 15 minutes. However, the actual generation time at 55 to 75 F and the resulting amount of foam formed at the top of the water bath could be estimated only within wide limits. Accordingly, the Sponsor requested, because of the urgent need for such a device, that a cursory investigation of the above-outlined general design be performed. This investigation was to consist of preparing a design sketch, conducting one or possibly two full-scale generations in a simulated generator, and modifying the design sketch. It was hoped that generation in the simulated generator would be sufficiently satisfactory that a sketch of a suitable generator design could be provided to the Sponsor within a relatively short period of time. This cursory program was set up under Work Order No. 10, Task Order No. 30.

When the above-outlined activity was performed, it was found that primarily because of the foam problem, further experimental efforts were needed in order to develop a generator which would satisfy the above-listed requirements. A research program directed toward achieving this goal was subsequently set up under Work Order No. 1, Task Order No. 39.

The research efforts performed on both of these programs are summarized below in chronological order, to provide a coherent picture of the entire development.

SUMMARY

This development was conducted in two parts. The first was a cursory investigation of the possibility of generating 300 cubic feet of hydrogen gas using Hydripills® and water with a one-package chemical addition, and was performed under Work Order No. 10, Task Order No. 30. The results of this initial limited effort indicated that sufficient foaming was experienced to necessitate further experimental work to develop a generation system.

The second phase consisted of a more extensive investigation of the possibility of generating 300 cubic feet of hydrogen gas using Hydripills® and water with a one-package chemical addition. This included the design and construction of the generator proper, of the chemical-addition container, and of related components, and was performed under Work Order No. 1, Task Order No. 39.

The ultimate objective of these efforts was achieved. A hydrogen generator was developed that satisfied all of the stated requirements except

one-the maximum allowable generation time of 25 minutes was exceeded. However, the Sponsor indicated that this maximum time specification can readily be changed to 40-45 minutes without presenting any problems.

RESEARCH ACTIVITY

The research activity consisted of an initial cursory investigation of the design parameters of a proposed 300-cubic-foot generator; a subsequent study of selected factors affecting the design and operation of the proposed generator; and the preparation and evaluation of an experimental generator. Following a successful demonstration, a final experimental generator system, i.e., generator plus associated components, was prepared incorporating selected modifications.

Simulated 300-Cubic-Foot Generator

On the basis of the work conducted previously under Task Order No. 15, it was estimated that approximately 9 pounds of chemical (Hydripills®) added to about 45 gallons of water would satisfactorily generate 300 cubic feet of hydrogen. Based on these figures, a simulated generator was constructed from a modified 100-gallon metal tank for a cursory evaluation of the previously estimated design parameters (Figure 1).

In addition to the simulated generator, a container for the chemical was fabricated. This was made from woven glass cloth, such as used for window screening, and was fashioned into a tubular configuration 6 inches in diameter and 20 inches long.

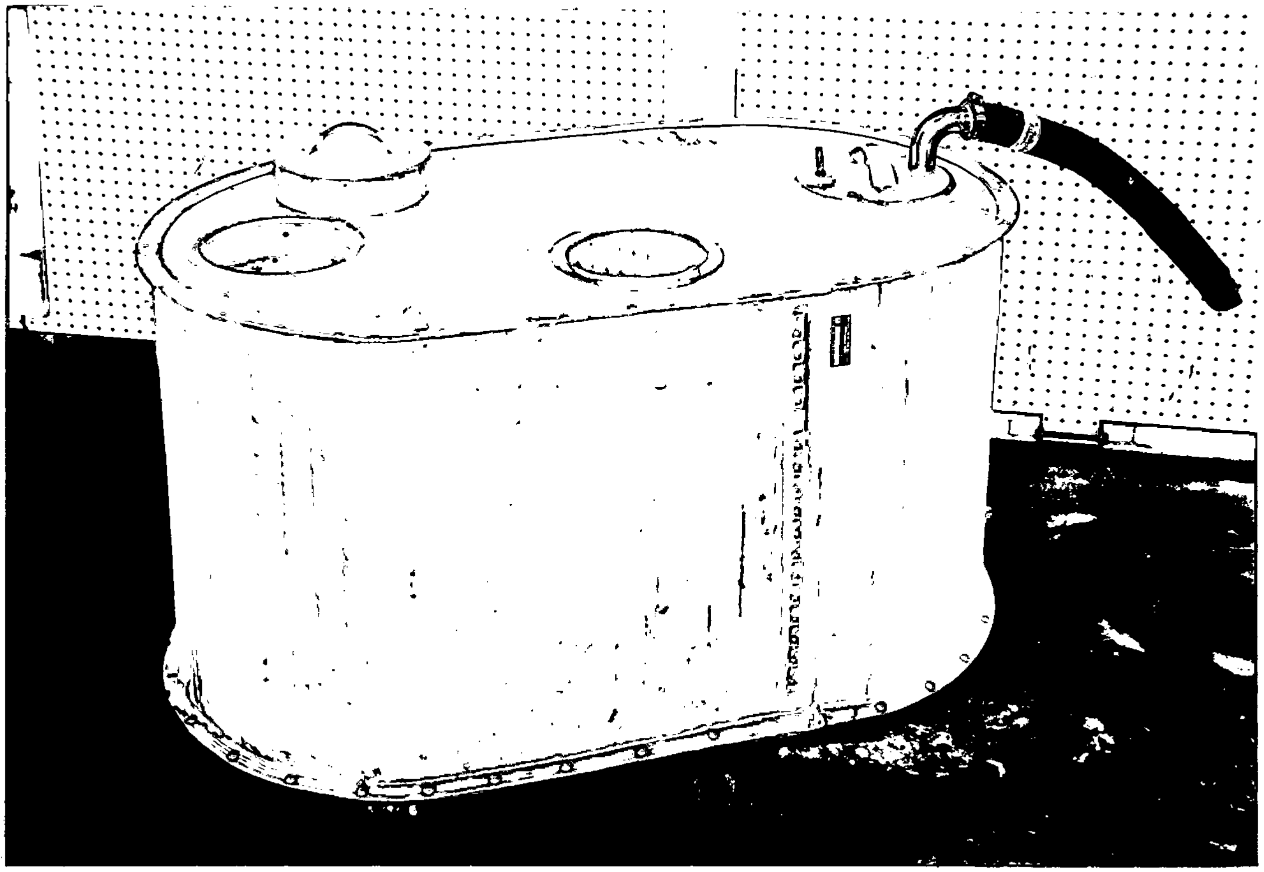

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Figure 1. Simulated 300-Cubic-Foot Generator

First Full-Scale Generation

On May 6, 1964, one generation test in the simulated generator was conducted. Even with the use of a chemical-addition tube and a baffle, both of which have aided in controlling the foam in previously designed generators, sufficient foaming was experienced to terminate the experiment prematurely, i.e., after about two-thirds of the generation was completed. Subsequent discussion indicated that because of the cost of the chemical and the amount of chemical needed for each generation, methods for controlling foam could probably be developed most satisfactorily by an empirical approach; and also that further experimental efforts were required to develop a suitable generating system.

For subsequent experiments, the chemical container was fabricated from metal cans so that changes in design of the container perforations might be readily accomplished. It was known from previous similar efforts that properly sized and located holes in the chemical container would regulate the chemical reaction in the water, and that the appropriate size and location of the holes could best be determined empirically.

As shown in Figure 2, an experimental metal chemical container was fabricated for a second full-scale generation in the simulated generator. The container consisted essentially of two 1-gallon cans soldered together (with the bottom removed from the top can). The number, size, and location of the drilled holes were selected arbitrarily; the single holes, one located on the bottom of the container and one at the top edge, were to assure the initial entry of water into the container and also the subsequent complete filling of the container with water.

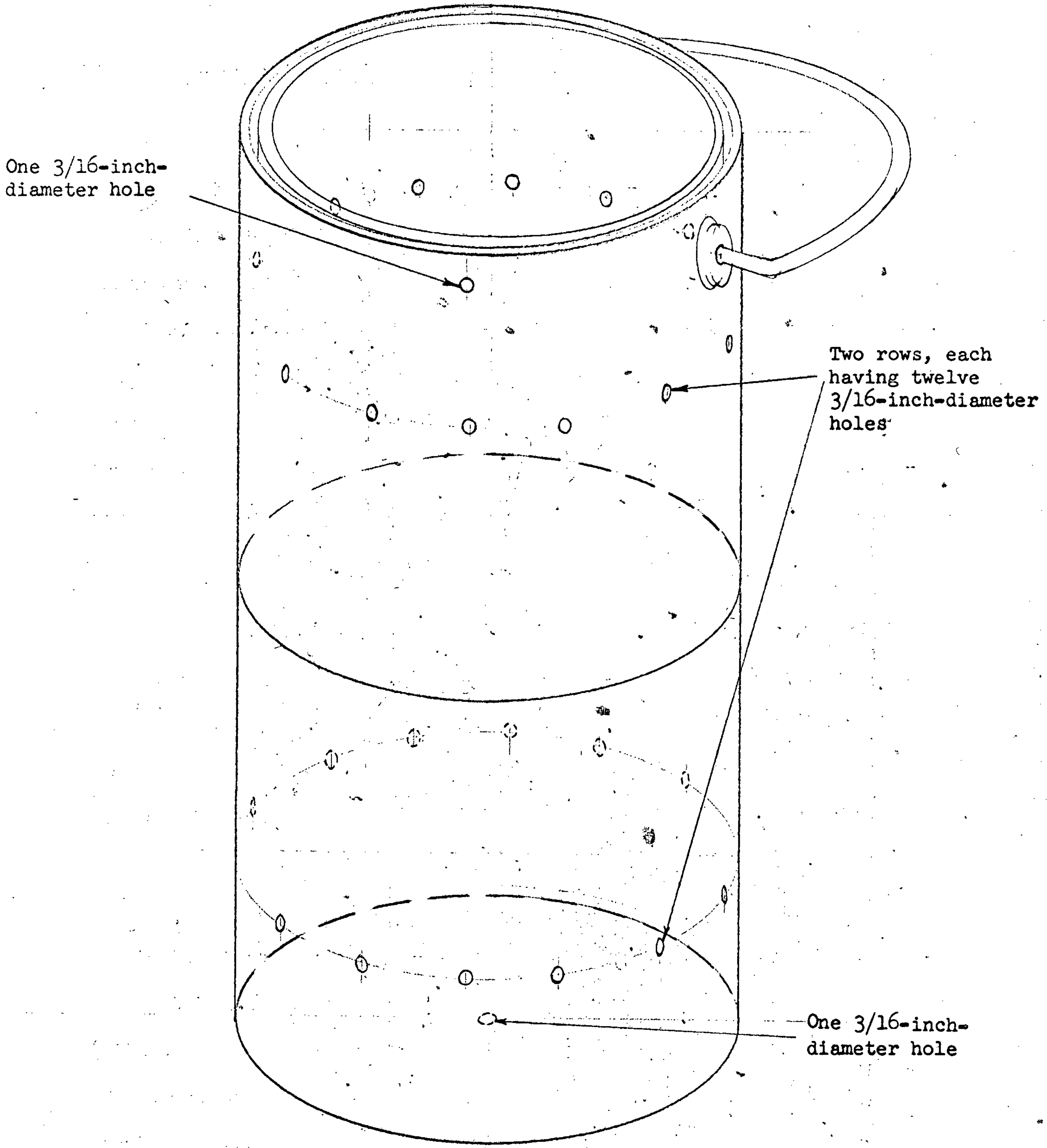

Figure 2. Two-Gallon Experimental Metal Chemical Container (for Full-Scale Test)

Second Full-Scale Generation

8.6 pounds of chemical was placed in this experimental chemical container and about 45 gallons of 60 F water was poured into the simulated generator. The chemical container was then inserted via the chemical-addition tube. The start of the resulting chemical reaction was almost immediate. The generation rather quickly became so vigorous that the friction-fitting lid which had been placed on the chemical-addition tube had to be held in place. The vigorous reaction lasted for 6 minutes. The chemical-addition-tube lid was removed, and the chemical container was jostled. The vigorous reaction started again, and lasted for an additional 4 minutes. Thus, a total time of 10 minutes was recorded for this generation. It appeared that with such a vigorous generation reaction, a reduction of the area of the holes in the chemical container was needed.

Experimental 300-Cubic-Foot Generator

In order to reduce the number of variables associated with the subsequent generation experiments, it was decided that a fabric full-scale generator would be fabricated such that the dimensions would more closely resemble those of the ultimate design. Two units were constructed in the course of the program. One reflected a preliminary design and was used to grossly check out the design parameters. After the below-described generation tests were run in the preliminary unit and the unit was demonstrated to the Sponsor, the final experimental unit was prepared, to reflect selected modifications as outlined below.

The general dimensions of the final experimental generator were 24 inches square by 38 inches high. These dimensions provided a volume of about 12.7 cubic feet or about 95 gallons. When the necessary quantity of water that had been established as 46 gallons was added, there was a free-foam volume above the water surface that was about 20 inches high. As seen in Figure 3, the experimental 300-cubic-foot generator resembled the previously designed 28-cubic-foot unit. It consisted of a rectangular-cross-sectioned unit fabricated from 16-ounce neoprene-coated nylon fabric with cemented and sewn seams. Four vertical 3/8-inch-diameter aluminum rods were used as supporting stays. An 8-inch-diameter neoprene-coated-nylon fabric tube (chemical-addition tube) provided entry for the chemical container. A polyethylene gas-outlet tube, 1-3/4 inches in ID, was incorporated in the top of the generator. This provided a stub for the attachment of the gas-outlet hose (automotive corrugated defroster hose) by means of a metal hose clamp. In addition, a 1-3/4-inch-ID polyethylene tube was built in near the bottom of the generator, for attaching a drain tube (2-inch-ID neoprene-coated nylon fabric tube) by means of a metal hose clamp. The 8-inch-diameter chemical-addition tube was designed to facilitate insertion of the chemical container into the generator and also to permit fast closing or opening of the tube.

In an operation, the drain tube is clamped off and water is added to the generator through the chemical-addition tube. The gas-inlet tube of the balloon is inserted over the generator gas-outlet hose, and taped in place. Then the chemical container is introduced into the generator through the chemical-addition tube, and the chemical-addition tube is clamped off. The chemical container floats partially under the water and releases the hydrogen gas as the chemical reaction takes place.

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Figure 3. Final Experimental 300-Cubic-Foot Generator

Following the construction of the 300-cubic-foot generator, one half-scale and three full-scale generations were conducted. Some experimentation with the design of the chemical container was performed simultaneously.

Half-Scale Generation

The first generation in the fabric generator was a half-scale test. The chemical container used (Figure 4) was of 1-gallon capacity and held approximately 4.3 pounds of chemical; the number and size, and generally the location of the holes were the same as in the previously described full-scale (2-gallon) container. In this test 23 gallons of 70 F water was used. The generation was completed in 18 minutes, with a temperature rise of 50 F to a maximum generation temperature of 120 F. There was no foam apparent at the gas-outlet hose, and the generation was not overly vigorous. This was considered an excellent generation.

Third Full-Scale Generation

A full-scale generation was conducted in the fabric generator. The full-scale (2 gallon) metal container was filled with 8.6 pounds of chemical and introduced into 46 gallons of 60 F water. The total generation time was 15 minutes and the temperature rise was 50 F, to a maximum generation temperature of 110 F.

This full-scale generation was satisfactory for the test conditions. However, it was determined that, if the initial water temperature in the generator was significantly higher than 60 F, say, by 10 to 20 F, an

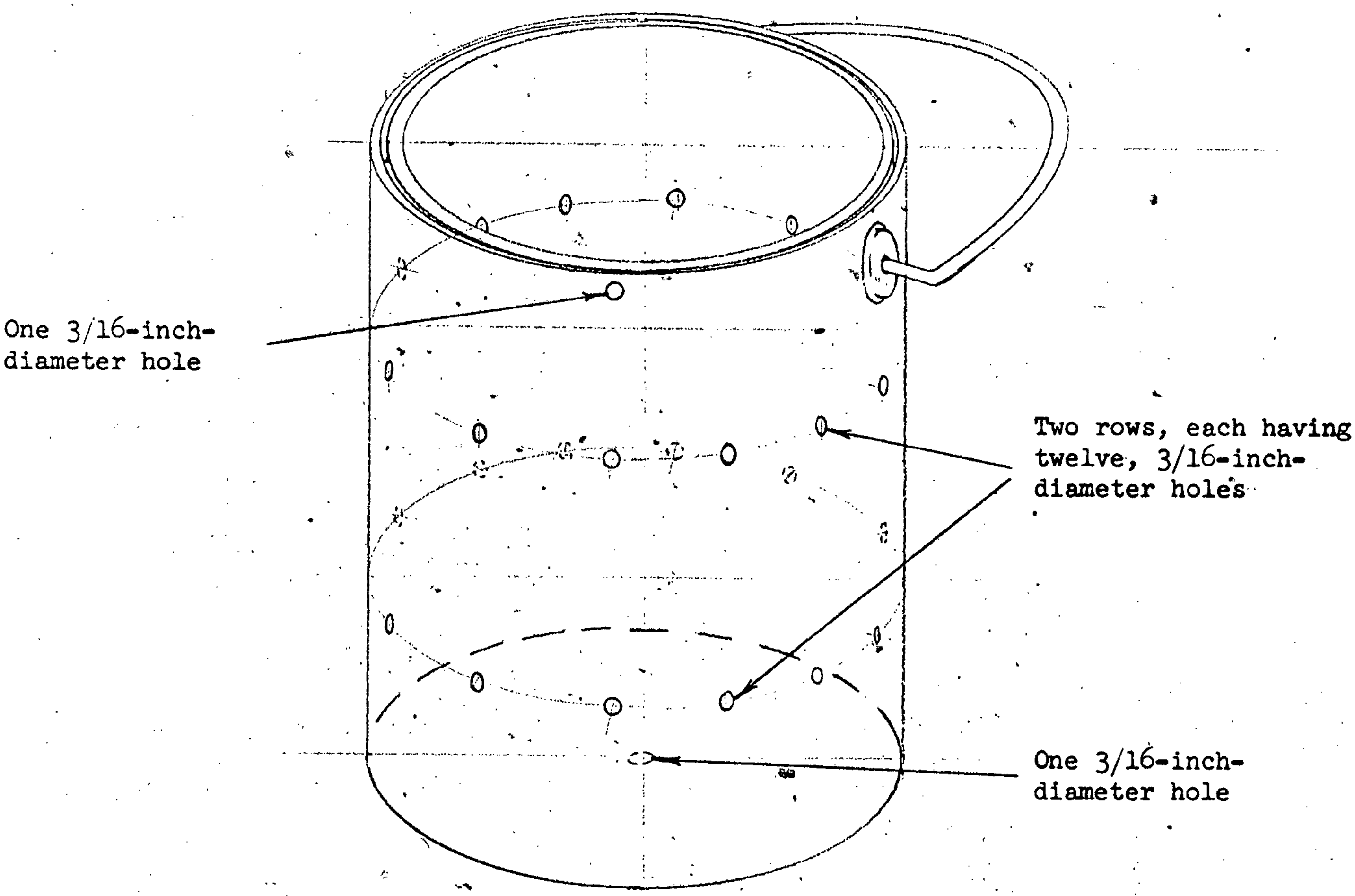

Figure 4. One-Gallon Experimental Metal Chemical Container (for Half-Scale Test)

unsatisfactory or overly vigorous chemical reaction, i.e., an excessively rapid reaction, could occur. Thus, it was decided that the area of the water-inlet holes in the chemical container would be reduced by one-fourth. This was accomplished by using 18 holes in two rows in the container instead of the previous 24 holes. At that time, it was also decided to make the chemical container from 16-ounce neoprene-coated nylon fabric; this would reduce the packaging size of the chemical container in that it could be folded and easily stored when not filled with the chemical. Thus, the fabric chemical container was generally the same as the full-scale metal container previously described, except that 18 holes, instead of 24 holes, were approximately aligned in the two rows. To assure the complete reaction of the chemical with the water when this chemical-addition bag was used, a 2-pound weight was attached to the bottom of the bag, so that the bag would submerge completely in the water near the end of the chemical reaction.

Final Full-Scale Generations

The fourth full-scale generation was conducted with 8.6 pounds of chemical added to 46 gallons of 64 F water using the chemical-addition bag. The temperature rise of the water was 36 F, which gave a final water temperature of 100 F. The generation was quite satisfactory, with a total generation time of 37 minutes.

Subsequently, another full-scale test was conducted as a field demonstration for the Sponsor. For this demonstration, a Sponsor-supplied 300-cubic-foot polyethylene balloon was used to receive the generated hydrogen gas. As before, 8.6 pounds of chemical was added to 46 gallons of water using the bag. The initial water temperature was 77 F and the final water temperature 114 F. After a generation period of about 19 minutes, the balloon was pulled loose from the generator gas-outlet hose by a strong wind. The generation continued for an additional 4 minutes, making a total generation time of 23 minutes.

It is estimated that the balloon was 2/3 to 3/4 full at the time of detachment and contained 200 to 225 cubic feet of hydrogen gas. The measured free lift of the balloon at that time was approximately 14 pounds. The Sponsor judged the equipment and the operation to be quite satisfactory for the intended use.

Modifications

Following the field demonstration, several selected modifications were suggested for the system. These were:

(1) Providing a two-clip close-off clamp for the chemical-addition tube instead of a one-clip clamp, as was used in the demonstration.

(2) Reducing the packaged length of the 3/8-inch-diameter aluminum supporting stays by making each stay in two halves.

(3) Providing a collapsible bucket (instead of a hand pump) for filling the generator with water in the field.

These modifications were subsequently incorporated into the final generator system and one system was fabricated. The various components were checked for dimensions and weight; the weights are as follows:

Component	Weight, pounds
Generator (complete with gas-outlet hose, drain hose, and clamps, but without aluminum supporting stays)	6.24
Chemical-addition bag (empty)	2.04
Aluminum supporting stays	0.94
Total net weight	9.22
Balloon weight	2.18
Chemical (addition for one generation)	8.60
Collapsible bucket	2.1
Total gross weight	22.10

The final generating system is shown in Figure 5.

Sketches showing the general construction of the generator components were completed and the system was packaged for shipment. The sketches and the complete system are to be shipped to the Sponsor.

FUTURE WORK

No future work is currently contemplated on the 300-cubic-foot hydrogen generator.

We have enjoyed working on this development. If there are any comments or questions regarding these efforts, we would be pleased to hear about them.

Sincerely,

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Figure 5. Experimental 300-Cubic-Foot Generating-System Components.
(The fabric chemical bag is shown on the left; the collapsible bucket on the right)